The COHERENT experiment

COHERENT collaboration

1. Name of Experiment/Project/Collaboration: **COHERENT**

2. Physics Goals

   a. Primary: measurement of **coherent elastic neutrino-nucleus scattering (CEvNS)**. Initial goal is unambiguous detection of CEvNS over background. The associated physics goals for the first measurements include limits on non-standard neutrino interactions and weak mixing angle measurement in a new channel. Subsequent goals (future phases): neutrino magnetic moment searches and neutron distribution measurements.

   b. Secondary: measurement of other **charged- and neutral-current neutrino interactions in the few tens of MeV range**, relevant for supernova-neutrino and other physics; in particular, cross sections of **neutrino-induced neutrons** on lead and other targets, which are relevant for supernova-neutrino detection.

3. Expected location of the experiment/project: **Spallation Neutron Source (SNS)** at Oak Ridge National Laboratory, Tennessee.

4. Neutrino source: **pion decay at rest** in the SNS target.

5. Primary detector technology: we aim to deploy as many different neutrino detector materials as feasible (measurements with materials with different N and Z give an advantage for probing new physics [1]) . Under consideration for deployment in the short term are CsI[Na], a liquid xenon two-phase TPC, and Ge PPC detectors. The order of deployment will be based on availability of detectors and final results of background measurements. We are also considering NaI, although this prospect needs further study.

6. Short description of the detector (s):

   – **CsI[Na]**: 15 kg crystal in first phase, with lead shield, muon veto, and neutron moderator and absorber (see [2]). Lead shield is already deployed at the SNS.

   – **Germanium PPC detectors**: point contact High-Purity Germanium (HPGe) detectors, similar to those used by the Majorana collaboration [3], active mass 10-20 kg in first phase.

   – **Liquid xenon two-phase**: time-projection chamber sensitive to single ionization electrons (see [4], with 100 kg mass.

7. List key publications and/or archive entries describing the project/experiment:

   – Most recent description of current plans:
   `https://fsnutown.phy.ornl.gov/fsnufiles/positionpapers/Coherent_PositionPaper.pdf`

   – Snowmass white paper [5].

   – More comprehensive white paper describing broad neutrino physics opportunities at the SNS [6].

   – Physics concept paper [1].

8. Collaboration

   a. Institution list: UC Berkeley, U. of Chicago, Duke U., U. of Florida, Indiana U., ITEP, LANL, LBNL, MEPhI, NCCU, ORNL, PNNL, Sandia, U. of Tennessee, TUNL

   b. Number of present collaborators: $\sim$45

   c. Number of collaborators needed: more would be welcome; specific needs will depend on selected technology path.

9. R&D

   a. List the topics that will be investigated and that have been completed:

* The three detector technologies under consideration for first deployment do not need significant R&D. (Sodium iodide needs more study.)
* Beam-related neutron backgrounds: this is a key issue for siting and final shielding design, to be addressed by beam simulation and (more importantly) by onsite measurements. A background measurement campaign in 2013-2014 has yielded some promising results (described in [7]); however further measurements are ongoing. A low-beam-neutron background basement site (with some overburden for cosmics also) suitable for the CsI detector, and possibly the other detectors, has been located. We are investigating other sites, both in the basement and on the surface.
* Neutrino-induced neutrons: this is a secondary physics goal in itself, but understanding of the rate will be needed to optimize shielding design for final CEvNS measurement configurations. The rate needs to be understood in order to determine whether redesign of CsI shield is necessary.
* Beam simulation, to understand the neutrino flux components. For the first phase, this is not the most critical item, but it will eventually become necessary to reduce flux systematics below 10%.

b. Which of these are crucial to the experiment: as indicated above, understanding the beam-related neutron background is the most critical, as it drives siting and shielding design for the first (and later) phases.

c. Time line: we expect measurements and shielding design for the first phase to be completed by mid-2015.

d. Benefit to future projects: other neutrino experiments at the SNS will benefit greatly from understanding of neutrino fluxes and backgrounds.

10. Primary physics goal expected results/sensitivity:

a. For exclusion limit (such as sterile neutrino search), show 3-sigma and 5-sigma limits: N/A

b. For discovery potential (such as the Mass Hierarchy), show 3-sigma and 5-sigma: [8]

c. For sensitivity plots, show 3-sigma and 5-sigma sensitivities: see, e.g., [1],[8].

d. List the sources of systematic uncertainties included in the above, their magnitudes and the basis for these estimates: dominant uncertainties on the measurement rate measurement will be beam-related backgrounds, detector energy scale, and neutrino flux uncertatinies. For "first light" discovery, results will most likely be statistics dominated.

e. List other experiments that have similar physics goals: CENNS at the Fermilab Booster Neutrino Beam [9], several reactor-based efforts (not all currently ongoing) with various technologies, e.g., [10–13]. RICOCHET is a reactor-based [14] proposal using bolometric detectors.

f. Synergies with other experiments: the results will be valuable for all direct dark matter detection experiments, as CEvNS of natural neutrinos represents a "background floor" for these. Any other neutrino experiment at the SNS (OscSNS, possibly eventually CAPTAIN or a similar experiment) will benefit from understanding of flux and of backgrounds. We note also that neutron-scattering experimentalists also have interest in our background studies, and we have SNS personnel from this community in our collaboration. There is also some "sociological" synergy with PROSPECT; although COHERENT and PROSPECT do not share physics goals or particular site, they are both neutrino experiments located at ORNL.

11. Secondary Physics Goal

a. Expected results/sensitivity: we expect statistically-significant detection of neutrino-induced neutrons on lead within 2015 using liquid scintillator deployed in the CsI shield; additional detectors using scintillators inside the shielding are also being deployed.

b. List other experiments that have similar physics goals: to our knowledge there are no existing or planned experiments with the goal of measuring neutrino-induced neutrons on lead or other heavy target materials in the few tens of MeV regime. (CAPTAIN-BNB has the goal of measuring cross sections on argon).

12. Experimental requirements

a. Provide requirements (neutrino source, intensity, running time, location, space,) for each physics goal.
COHERENT is entirely parasitic to the SNS, which is already a near-ideal neutrino source for CEvNS and satisfies our requirements. The required detector footprint will depend on specific detector technology and shielding optimization; $1.5 \times 3 \times 1.5$ m for Ge is conservative. The selected site must have sufficiently low beam-related neutron background. For future upgrades we may consider a borehole pit ($\sim$10-m depth) outside the SNS target building for future upgrades.

13. Expected Experiment/Project time line

    a. Design and development: < 1 year.

    b. Construction and Installation: <1 year for first-phase CsI; 1-2 years for Ge and LXe.

    c. First data: in ~ 1 year for first-phase CsI; in 1-2 years for Ge and Xe.

    d. End of data taking: in 4-5 years.

    e. Final results: in 5-6 years

14. Estimated cost range: depends on technology deployed.

    a. US contribution to the experiment/project: depends on technology choice; <\$0.1M for first-phase CsI; ~\$1M for LXe (shielding and installation); \$1-2M for Ge (detectors, shielding, installation), depending on mass deployed.

    b. International contribution to the experiment/project: Russia would contribute LXe detector.

    c. Operations cost: \$25-50K per year (CsI), ~\$50-100K /year (LXe, Ge)

15. The Future

    a. Possible detector upgrades and their motivation: the first phase results will be statistics dominated; the obvious upgrade will be larger detector(s). It is also desirable to deploy different materials, with different values of N and Z, for cancellation of systematics and probing of new physics. Other possibly desirable upgrades: lower threshold detectors will enable sensitivity to neutrino magnetic moment. For lower background conditions, a borehole outside the SNS target might be considered. A second target station at the SNS is also a long-term future possibility.

    b. Potential avenues this project could open up: this is a completely new channel for exploration of weak physics. Anomalies with respect to standard model predictions will indicate new physics to be explored.

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[1] K. Scholberg, Phys.Rev. **D73**, 033005 (2006), hep-ex/0511042.
[2] J. Collar *et al.*, (2014), 1407.7524.
[3] Majorana Collaboration, N. Abgrall *et al.*, Adv.High Energy Phys. **2014**, 365432 (2014), 1308.1633.
[4] D. Y. Akimov *et al.*, JINST **8**, P10023 (2013), 1212.1938.
[5] D. Akimov *et al.*, (2013), 1310.0125.
[6] A. Bolozdynya *et al.*, (2012), 1211.5199.
[7] J. Adam *et al.*, 2014, `https://fsnutown.phy.ornl.gov/fsnufiles/positionpapers/Coherent\_PositionPaper.pdf`.
[8] 2015, In preparation.
[9] S. Brice *et al.*, Phys.Rev. **D89**, 072004 (2014), 1311.5958.
[10] H. T. Wong, Mod.Phys.Lett. **A23**, 1431 (2008), 0803.0033.
[11] CoGeNT Collaboration, J. Collar, J.Phys.Conf.Ser. **136**, 022009 (2008).
[12] S. Sangiorgio *et al.*, Phys.Procedia **37**, 1266 (2012).
[13] 2013, `http://neutrinos.llnl.gov/cns_workshop_agenda.html`.
[14] J. A. Formaggio, E. Figueroa-Feliciano, and A. Anderson, Phys.Rev. **D85**, 013009 (2012), 1107.3512.